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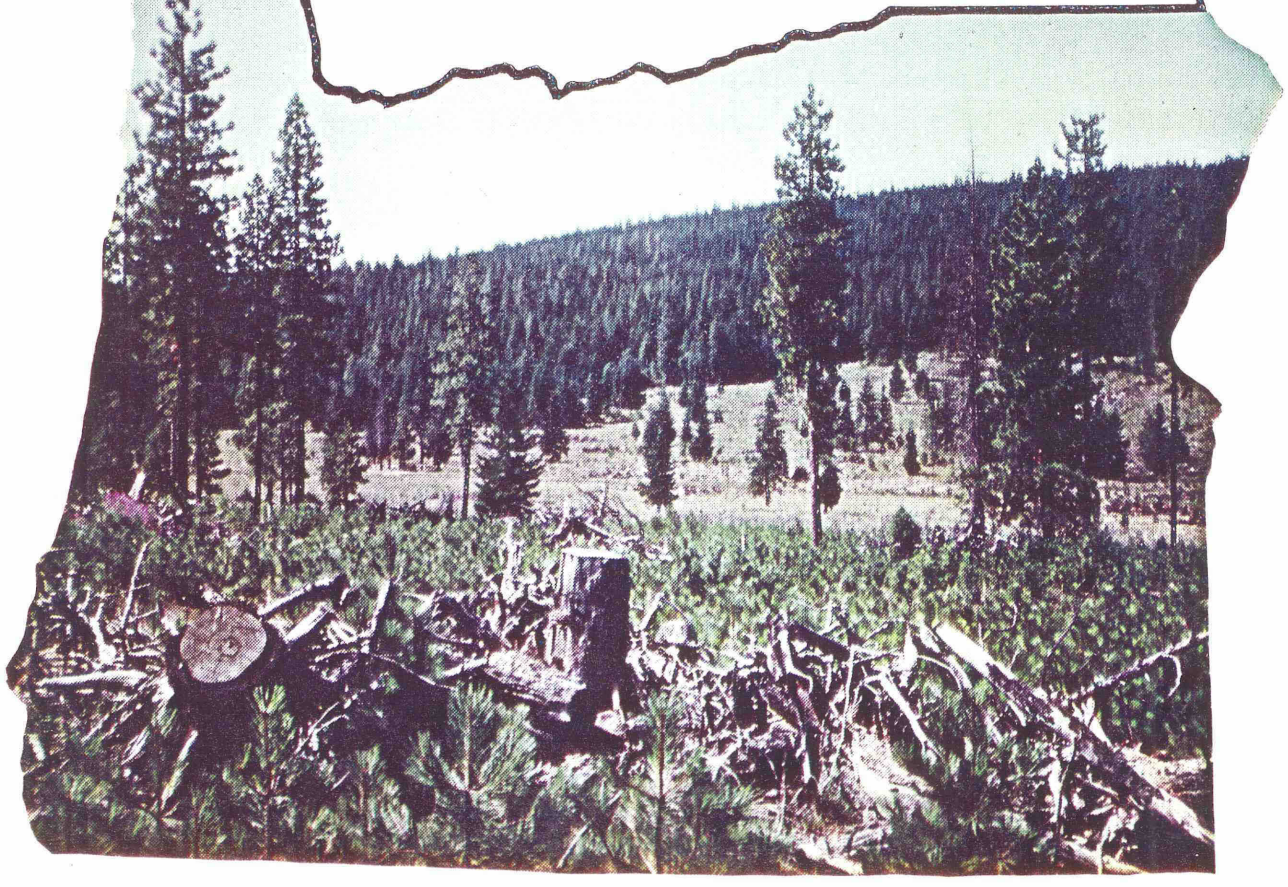
ECONOMICS OF CONTROLLING LAMINATED ROOT ROT IN PACIFIC NORTHWEST FORESTS



Economics of Controlling Laminated Root Rot in Pacific Northwest Forests

by

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SUMMARY

Present net values (PNV) of several control strategies for laminated root rot were compared on 18 hypothetical sites in the Pacific Northwest. In most instances, planting less susceptible species is a better strategy over three rotations than continuously managing species highly susceptible to laminated root rot. A comparison of PNV improvements results in the following ranking for infected Douglas-fir stands on the west side of the Cascades - western hemlock > noble fir > white pine > western redcedar > Douglas-fir > red alder. However, with certain treatments and sites, red alder produces higher PNV's than Douglas-fir. In infected white fir stands on the East side, ponderosa pine is the only species that yields a higher PNV over three continuous rotations. However, if a first shortened rotation of white fir is grown followed by two rotations of less susceptible species, the ranking is ponderosa pine > lodgepole pine > western larch > white fir. Stump treatment as an alternative to species manipulation also shows good financial gains over continued cropping of Douglas-fir or white fir on infected sites. Financial gains of treating infected sites increase with site class and disease levels, the latter being more critical. Also, the better treatments should be performed at the beginning of the first rotation to yield the highest PNV's after three rotations. Land managers can evaluate the economic viability of treatment options with locally obtained volume yield, stumpage prices, and loss information using the methods outlined in this report.

INTRODUCTION

Forest root pathogens are insidious, difficult to control, and rank as some of the most destructive agents in Pacific Northwest forests (Childs and Shea 1976, Filip and Goheen 1982, 1984). Control strategies mainly involve silvicultural treatments such as planting or thinning to favor indigenous species that are less susceptible to the root disease(s) present (Hadfield and Johnson 1977). However, more resistant species often produce lower volume yields or have lower stumpage values than highly susceptible species on a similar, yet healthy site.

Recently, treatment of infected stumps and roots has been suggested as a means of root disease control (Roth and others 1977, Filip and Roth 1977, Thies and

Nelson 1982, Thies 1984). Infected stumps and roots from trees of the previous stand serve as inoculum bases for pathogenic fungi to infect future stands on the same site. These fungi may remain viable for as long as 50 years, depending on stump and root size. The hypothesis is that removing stumps and roots from the soil with subsequent desiccation and death of root pathogens, or fumigating in-place by injecting wood with highly volatile chemicals will reduce infection and mortality in subsequent stands on that site. Stump treatment by any means is costly, and therefore, may not pay for itself when attempted on low productivity sites or with less valuable timber species.

In this paper, we explored the economics of several control strategies for laminated root rot caused by *Phellinus weirii*, one of the more damaging root diseases in the Pacific Northwest. The control strategies are defined in terms of both type and timing of treatment. We chose 18 hypothetical sites in the Pacific Northwest and compared present net value (PNV) of each strategy over three rotations. Without treatment, damage caused by *P. weirii* would be at least the same as that in the previous rotation and probably would increase with subsequent rotations (Hadfield and Johnson 1977, Tkacz and Hansen 1982).

METHODS

The method of analysis can be conveniently divided into four areas. These are (1) delineation of sites and disease conditions for analysis; (2) formulation of stand treatment alternatives; (3) estimation of yield impacts for each treatment alternative; and (4) economic evaluation procedures.

1. Sites

Eighteen hypothetical sites were selected that were representative of both West Side (west of the Cascade Crest) and East Side (east of the Cascade Crest) forest types. Three levels of site productivity (poor, average, good site class) were chosen for both West Side and East Side areas. These corresponded to Douglas-fir site indexes $_{50}$ of 80, 100, and 120 (West Side) and white fir site indexes $_{50}$ of 57, 75, and 100 (East Side). Within each site class, three levels of initial root disease (10, 35, and 50 percent initial area infected) were assumed.

2. Stand Treatments

Treatments differ by method of disease control and timing of the treatment. Application of treatments to a site varied with the initial disease condition and level of management assumed for the site.

Control methods. Two approaches to controlling the disease on infected areas were analyzed:

1. Sanitizing the infected area through either stump removal or fumigation.

2. Reestablishing an infected area with either a less susceptible host or a nonhost species.

Because of differences in both susceptibility and value, several substitute species were evaluated. On the East Side, these included ponderosa pine, larch, and lodgepole pine; on the West Side, hemlock, cedar, white pine, alder, and noble fir were considered.

Timing. The time at which treatment is implemented during a rotation can greatly influence its economic viability. To provide information on how this can influence economic return, the following treatment timings were considered:

1. Beginning of first rotation.
2. Precommercial thinning of first rotation.
3. Commercial thinning of first rotation.
4. Beginning of second rotation.

No thinning was assumed in the 18 hypothetical stands because of the difficulty of obtaining yield and disease loss data for thinned material or additional volume gain in residual trees for most tree species. However, some treatments were applied at ages when stands normally would be thinned. The timing of these treatments is described in this text as precommercial thinning or commercial thinning age even though none of the stands were thinned.

West Side precommercial thinning age was 15 years for all site classes. Commercial thinning age was 45, 55, or 65 years for stands on good, average, or poor sites. Final harvest age, which was increased as site index decreased, was 60, 70, or 80 years for stands on good, average, or poor sites.

East Side precommercial thinning age was 20 years for all sites. Commercial thinning age was 60, 70, or 80 years for stands on good, average, and poor sites. Final harvest age was 80, 90, or 100 years for stands on good, average, or poor sites.

Application. Sites were delineated into healthy and infected portions. Healthy sections were treated as normal with site prep, planting, and final harvest. Only infected portions were subjected to stump treatment or were planted with less susceptible species. In stands treated at the beginning of the first or second rotation, both healthy and infected portions were harvested simultaneously (Figure 1).

Trees within infected portions of stands treated at precommercial thinning age were destroyed and the site prepared and planted. For most species, the treated portion of the stand was grown to the end of the first normal rotation and harvested with the healthy portion of the stand (Figure 2). For species with slower juvenile growth such as cedar, white pine, noble fir, and ponderosa pine, the treated portion of the stand was harvested at the end of the second normal rotation with the healthy portion of the stand (Figure 3).

Trees within infected portions of stands treated at commercial thinning age were harvested and the site prepared and planted. All species in treated areas were harvested with the healthy portion of the stand at the end of the second normal rotation (Figure 4).

3. Yield Impact Estimates

Evaluation of the treatment alternatives as applied to each site was made by estimating yields over three rotations. A yield estimate was also made for each site if no treatment was instituted. The steps of this estimation process accounted for differences in site productivity, species and associated disease impact, and areas of initial and final infection.

Site index values. To determine potential yields and reflect differences in productivity on the 18 hypothetical sites, it was necessary to determine site index values for different species on the same site. Since site index values are seldom the same for different species on the same site, the following cross-site index tables were used: Douglas-fir/western hemlock (Steinbrenner 1976), white fir[1/]/larch/lodgepole/ponderosa pine (Hall 1973), and noble fir/Douglas-fir (Franklin 1982). For other species, average yields of poor, average, and good site indexes were used.

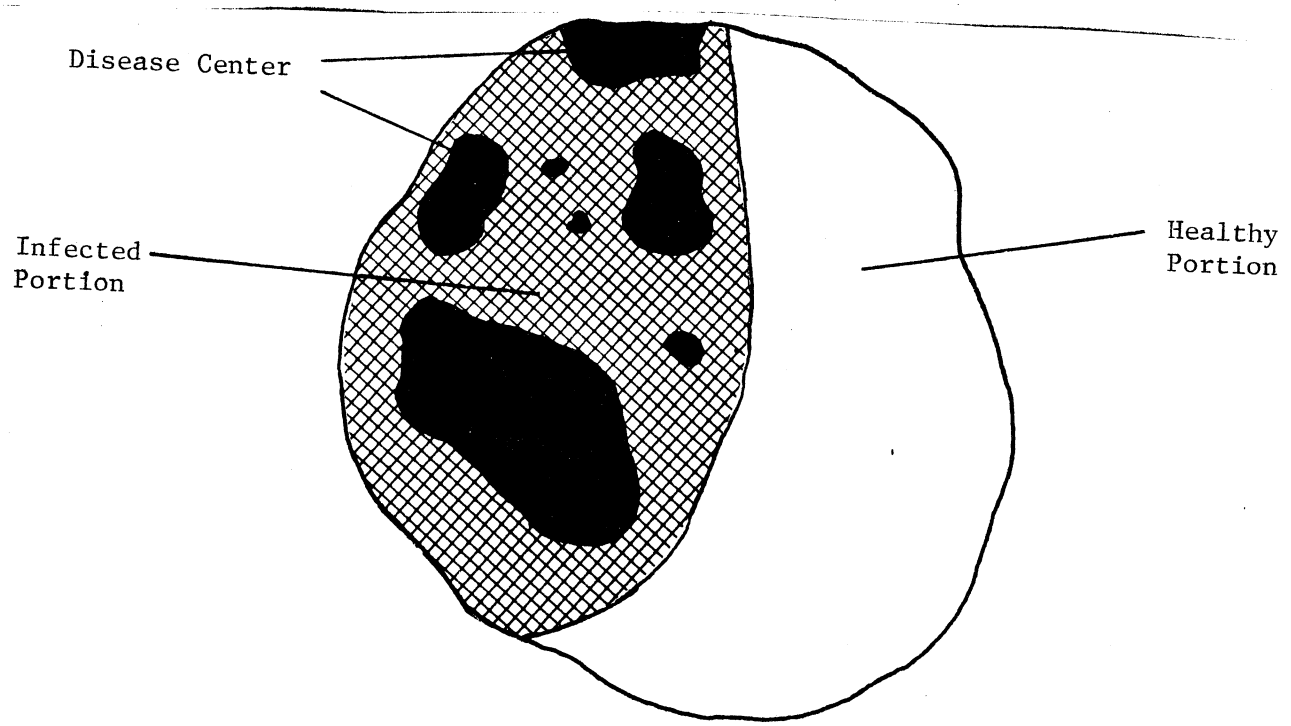
1/ White fir (*Abies concolor*) and grand fir (*A. grandis*) are closely related species that often hybridize where ranges overlap. Yields, stumpage prices, and degree of disease resistance are similar enough that both species were considered as one and are referred to as white fir in this report.

Yields. Gross board-foot yields for ten species were derived from empirical yield tables (Appendix) as follows:

Species	Source	Method of Calculation
Douglas-fir (West Side)	Chambers 1980	Percent Net Basal Area = 100%, 7.0 in. DBH minimum
Western Hemlock Red Alder	Chambers & Wilson 1978 Chambers 1974	6 in. top, 16-foot logs, Scribner
Noble Fir	Franklin 1982	1.3 x Douglas-fir bd. ft. yields
Western Redcedar	Smith, Walters, & Wiker 1961	4.5 x cubic foot yields
Western White Pine	Haig 1932	6.6 in. DBH min., Int. 1/8-in. rule, full stocking, 6 in. top, 16-foot logs
White Fir	Cochran 1979	4.5 x cubic foot yields, stumps
Western Larch	Schmidt, Shearer, and Roe 1976	4.5 x cubic foot yields, 0.6 in. DBH minimum
Lodgepole Pine	Dahms 1964	4.5 x cubic foot yields, 1.0 in. DBH minimum, stumps and tops
Ponderosa Pine	Meyer 1961	4.5 x cubic foot yields, 0.6 in. DBH minimum, stumps and tops

Disease losses. Damage caused by laminated root rot was expressed in two ways for all species: (1) yield loss within infected portions of the stand, and (2) expansion of infection into healthy portions of the stand.

The infected portion of a stand, as defined here, is that part of a stand that contains visibly infected areas or pockets with dead, dying, and windthrown trees.



In young stands of 10 to 30 years, root disease pockets may not be evident, but instead, scattered dead or dying trees occur throughout the area. Infected portions of stands may contain "healthy-appearing" trees in between disease centers. Many of these trees probably are infected also but do not show above-ground symptoms. Also, the infected portion of the stand contains a 100-foot wide buffer of healthy-appearing trees beyond visibly dead and dying trees. This buffer assures an effective zone of treatment. Also, the infected portion of the stand as defined here is a more practical area to treat rather than dealing with individual and often ill-defined disease centers.

Yield loss within infected portions of a stand was based on literature stating that highly susceptible species such as Douglas-fir and grand fir will sustain severe losses if planted on infected sites (Hadfield and Johnson 1977). Although yield losses for Douglas-fir or white fir within infected areas as defined here have never been reported, differences in merchantable basal area between healthy and infected areas of 27 to 38 percent in West Side Douglas-fir stands and 15 to 38 percent in East Side white fir stands have been observed in naturally-established stands surveyed by Forest Pest Management pathologists.

For our analysis, we separated infected areas from healthy areas and assumed a yield loss of 50 percent at the end of the rotation for the infected portions. Our hypothetical stands were all established by planting, and competing vegetation has been controlled; in other words, these are intensively managed sites. Mortality losses as high as 50 percent of the trees in a thinned 20-year-old plantation have been reported in the Coast Range of Oregon (Goheen and others 1984). Such plantations usually are established in infected areas that formerly had few openings but a high ratio between live infected and dead infected trees. The 50 percent yield loss in infected areas was also assumed for white fir in East Side stands.

We suggest using a yield loss of 25 percent at the end of the rotation for infected portions of stands that have been established naturally, are suffering from excessive competing vegetation, and occur in areas that formerly had many openings with a low ratio between live infected and dead infected trees.

Intermediately susceptible species such as noble fir, western hemlock, and larch will experience some damage when planted on infected sites, but they generally can be grown to full rotation with little loss (Hadfield and Johnson 1977). A yield loss of 10 percent at rotation age was assumed for noble fir, western hemlock, and larch on infected sites.

Root disease-tolerant species such as white pine and lodgepole pine will become infected, sustain loss primarily as butt rot, but infrequently will be killed if grown on infected sites. A yield loss of 5 percent at rotation age was assumed for white and lodgepole pine on infested sites.

Resistant species, such as ponderosa pine and western redcedar (West Side), and immune species, such as red alder, rarely will become infected (alder not at all) and sustain practically no loss. No yield losses were assumed for ponderosa pine, cedar, or alder.

Expansion rates of infection into healthy portions of a stand and expansion in replacement stands were based on data indicating increasing infection and damage in successive rotations of Douglas-fir (Tkacz and Hansen 1982). Expansion rates within stands where infected areas are planted with other species besides Douglas-fir are unknown but are assumed to be inversely proportional to degree of root disease resistance. The following expansion rates were assumed at the end of three rotations at three levels of initial infection:

PERCENT INCREASE IN AREA INFECTED BETWEEN ROTATIONS

Rotation	Highly Susceptible Species	Intermediately Susceptible Species	Tolerant, Resistant or Immune Species
		10% Initial Stand Infection	
First	15	11	10
Second	23	12	10
Third	35	13	10
		35% Initial Stand Infection	
First	53	39	35
Second	80	43	35
Third	100	47	35
		50% Initial Stand Infection	
First	75	55	50
Second	100	61	50
Third	100	67	50

Economic Evaluation Procedures

Implementing a disease control measure results in an additional cost of stand management. The intent of this action is to increase stand productivity and associated revenue to more than offset investment costs. If successful in this endeavor, the present net value (PNV) of managing a treated stand will increase over that of an untreated stand. This PNV financial gain is the economic criterion chosen to judge whether a treatment is a good investment and to what extent better than an alternative treatment.

The analysis evaluates all treatment opportunities, both type and timing, from the perspective of making a decision at the beginning of the first rotation. What is not addressed is the immediate application of treatment opportunities to infected stands of different ages. That is, the economic and other data presented in this report do not provide information for assessing whether it would be a better investment to treat a similarly infected stand ready for precommercial thin or one that is currently scheduled for its first commercial entry.

The stand and not the forest was selected as the management context for conducting this analysis. We wish to point out that a stand evaluation will not account for cumulative forest-wide disease impacts on more general forest management objectives. Considering these, our study results likely understate the benefit (PNV gain) resulting from a disease control measure.

Both the PNV of stand management and financial gain (loss) to disease treatment are influenced by several important assumptions about underlying economic data. As follows, primary among these are species stumpage prices, real price and cost projections, management and treatment costs, and discount rates.

Stumpage prices and projections. Stumpage prices (dollars per thousand board feet) were based on 5-year (1976-1981) values for Pacific Northwest tree species on National Forest lands (Ruderman 1982). Stumpage prices are statistical high bids, which are defined as bid price minus credit for road costs. They include an allowance for sale area betterment (K-V funds). Stumpage prices were adjusted downward for all species to account for smaller diameter material grown on shorter rotations. Stumpage prices were assumed to increase at a 1 percent annual growth rate after adjustment for inflationary price increases.

Species	Stumpage	Species	Stumpage
Douglas-fir	$203	White fir	$ 82
Western hemlock	152	Western larch	37
Western redcedar	101	Lodgepole pine	29
Red alder	10 1/	Ponderosa pine	119
White pine	91	Noble fir	111

1/ Estimate from Siuslaw National Forest

Site prep costs. West Side site prep costs were based on piling, burning, and spraying costs of $175/acre and planting costs of $80/acre for a total of $255/acre. Where stumps were treated, stump treatment (either excavation or fumigation), including piling and burning, was $500/acre with planting costs of $80/acre for a total of $580/acre. Costs of stand destruction at 15 years were $150/acre which included some site prep and planting costs.

East Side site prep costs were based on piling and burning costs of $95/acre and planting costs of $140/acre for a total of $235/acre. Where stumps were treated, stump treatment was $350/acre (because of smaller and fewer stumps on the East Side) with planting costs of $140/acre for a total of $490/acre. Site prep costs after stand destruction at 20 years were $150/acre Not included was the additional cost of removing Douglas-fir or white fir that regenerate naturally on sites where alternate species are planted. All costs were assumed to remain constant in real terms over the three rotation periods.

Harvest revenue. Harvest income at the end of each rotation was a product of gross yield, disease loss, and stumpage price. It was computed as an average of harvest income for infected and healthy portions of the stand. For example, if a Douglas-fir stand is 15 percent infected at rotation age, then 33,008 bf./ac. gross yield, 50 percent disease loss, and $202 stumpage would yield a harvest income of $3,334/acre = (33008 x 0.5 x 0.202) from the infected portion (15 percent) of the stand and $6700/acre = (33008 x 1.00 x 0.202) from the healthy portion (85 percent). The average harvest income for the entire stand for that rotation would be $6,196/acre = (0.15 x 3334) + (0.85 x 6701).

Present net values and discount rates. The following equation was used to compute for three rotations a PNV for each treatment using 4 and 7.25 percent discount rates:

$$PNV = \sum_i B_i * \left[\frac{1+p}{1+r}\right]^n - \sum_j C_j * \left[\frac{1+p}{1+r}\right]^{n-1}$$

Where

B_i = the ith benefit
C_j = the jth cost
P = benefit or cost annual appreciation rate (1% for benefit, 0 for cost)
r = discount rate (4 or 7.25 percent)
n = year of benefit or cost transaction
$\sum_i$ = operator indicating summation of all benefits or costs

The equation was solved with the aid of a programmable hand-held calculator using a program developed by the second author (copy of program available from FPM).

RESULTS AND DISCUSSION

Nearly 400 individual runs of the PNV equation were performed with 25 treatments on nine West Side sites and 17 treatments on nine East Side sites. Data are summarized in eight tables by differences in PNV among treatments, and numerical ranking of differences for both East Side and West Side locations under 4 percent and 7.25 percent discount rates. The following discussion pertains to treatments analyzed with a 4 percent discount rate which is currently used by the USDA Forest Service. The results of the 7.25 percent rate will be discussed if they are dramatically different from the 4 percent rate.

Treatments in General

1. Most of the treatments tested are better than continued growing of species highly susceptible to laminated root rot:

   -in either West Side or East Side stands
   -at any site class
   -at any disease level

2. Definite differences in PNV occur among treatments after three rotations. These differences, with some exceptions, hold true for all site classes, disease levels, and treatment times.

3. Treatments with better economic returns (planting of hemlock, noble fir, white pine, and ponderosa pine or stump treatment) should be effected at the beginning of the first rotation; otherwise wait until the stand is merchantable, then clearcut and treat at the beginning of the second rotation. No treatment should be performed on planted sites until the stand is merchantable, except on good or average West Side sites or in stands that are more than 50 percent infected.

4. If, because of other management considerations, the better returning treatments cannot be performed, then the poorer but postive returning treatments (planting of cedar, alder, lodgepole pine, and larch) should be implemented at the beginning of the second rotation following a first shortened rotation of Douglas-fir or white fir. However, if the Douglas-fir or white fir stands are more than 50 percent infected, implement the treatments at the beginning of the first rotation. Infected Douglas-fir and white fir will often bring higher financial returns in a short rotation than some alternative species. This is especially true when anticipated yield losses within infected areas are 25 percent or less or if a 7.25 percent discount rate is used.

5. The main difference in treating infected stands experiencing a 50 percent yield loss and treating stands with a 25 percent yield loss is that all treatments except planting of hemlock and ponderosa pine should be delayed until the first rotation stand is merchantable where a 25 percent yield loss is anticipated.

6. Financial gains of treating infected sites increase with site class and amount of infection. Treating sites with high site indexes and high disease levels yields the greatest financial gains after three rotations. Conversely, treating sites with low site indexes and low disease levels yields the poorest financial gains. However, disease level is more critical than site class. For example, treating poor sites with severe disease brings higher financial returns than treating good or medium sites with low disease levels. Infected sites should be prioritized based on this.

Stump Treatment

On all West Side sites and all but poor East Side sites, stump treatment delivers a high financial return. The financial benefits of growing near normal yields of Douglas-fir or white fir for three rotations on sanitized sites greatly offsets the high initial treatment costs. Should stump treatment costs be higher than we used or yields of Douglas-fir or white fir after treatment be lower than assumed (90 percent), the ranking could change. The effects of potential soil compaction and damage on yields following stump excavation are not known and could limit the use of this treatment on certain sites. Also, stump excavation is impractical on steep sites. Although stump fumigation may avoid the problems of soil destruction and steep topography, treatment is still experimental.

At a 7.25 percent discount rate on all sites, it is better to grow alternative species than to treat stumps.

Species Manipulation

With some exceptions, treatment ranking of less susceptible tree species does not change with site class or amount of disease. In West Side stands, highest PNV's are as follows: western hemlock > noble fir > white pine > cedar > Douglas-fir > alder. However, with certain treatments and sites, such as 1) first growing a shortened rotation of Douglas-fir followed by one rotation of alder and 2) growing alder at the beginning of a rotation on good sites, red alder produces higher PNV's than Douglas-fir. In East Side stands the ranking is: ponderosa pine > lodgepole pine > larch > white fir when a first shortened rotation of white fir is followed by two rotation of the less susceptible species. Noble fir and white pine, which were analyzed on West Side sites, can be grown where adapted on some East Side sites and are good alternatives to growing white fir on diseased sites. Also, the same may be true for all the species analyzed on East Side sites. On some West Side sites, these species could be substituted for Douglas-fir to reduce root disease losses.

Two factors, potential volume yield and stumpage price, greatly influence the financial returns for the species tested. Degree of disease resistance does not appear to be as strong a factor, especially in West Side stands where alder, the most resistant species, is ranked last and hemlock, the most susceptible species (except for Douglas-fir), is ranked first. A 10 percent yield loss was assumed for hemlock planted on diseased sites. If this estimate is less than actual, treatment rankings could change. Also, if stumpage prices change among species, such as for alder which had the lowest rate, then treatment rankings could change also.

Western hemlock (*Tsuga heterophylla*). Substituting western hemlock for Douglas-fir brings the best financial return when planted on sites with laminated root rot. Where adapted, hemlock will out-produce all other species, except noble fir, at all site classes. Except for Douglas-fir, stumpage prices for hemlock are higher than any other species analyzed. Hemlock is generally more defective than other West Side species and is often infested with dwarf mistletoe (*Arceuthobium tsugense*). However, damage from either decay or dwarf mistletoe will be minimal in intensively managed stands grown on short rotations (120 years). Mountain hemlock (*T. mertensiana*) is highly susceptible to laminated root rot and should not be substituted for western hemlock. Since western hemlock harbors *P. weirii* infection that can spread to Douglas-fir, infected areas planted with hemlock should not be planted with Douglas-fir in any future rotation.

Noble fir (*Abies procera*). Of all West Side species, noble fir is the second best alternative species to substitue for Douglas-fir on root-diseased sites. Noble fir grows slowly at first, but yields at rotation age will exceed that of any other species at all site classes. Noble fir is more prone to decay than Douglas-fir, but much less so than hemlock. Also, in some areas, hemlock dwarf mistletoe and associated canker fungi will infect noble fir and cause growth loss and tree mortality. As with hemlock, short rotations will minimize this damage. Infected sites planted with noble fir should not be planted with Douglas-fir in the next rotation because of disease carryover from noble fir to Douglas-fir.

Shasta red fir (*A. magnifica*) is closely related to noble fir, has a similar susceptibility to laminated root rot, and could be substituted for noble fir on

appropriate sites. Two other species of true fir, Pacific silver fir (*A. amabilis*), and subalpine fir (*A. lasiocarpa)* on certain sites appear to be as susceptible to laminated root rot as Douglas-fir or white fir. Currently, it is recommended that these species not be substituted for Douglas-fir.

Western white pine (*Pinus monticola*). Western white pine is the third best species to substitute for Douglas-fir in root-diseased areas. White pine grows relatively well, especially at high elevations. White pine normally has minimal defect and generally is not affected by dwarf mistletoe. Severe losses from white pine blister rust (*Cronartium ribicola*) have decimated white pine stands throughout the host range. However, the selection and propagation of blister rust-resistant trees has greatly increased successful management of white pine. Use of blister rust-resistant planting stock on high hazard sites and cultural techniques, such as pruning and microsite *Ribes* removal, make white pine a good species to plant on sites affected by laminated root rot. Sugar pine (*P. lambertiana*) is as resistant to laminated root rot as white pine and could be substituted on appropriate sites. Infected areas planted with white or sugar pine should not be planted with Douglas-fir in the next rotation because of possible disease carryover from pine to fir.

Western redcedar (*Thuja plicata*). Cedar is the fourth best species to substitute for Douglas-fir in root-diseased areas. However, there is speculation that Douglas-fir can be grown with minimal loss after one rotation of cedar. If true, this would improve greatly the ranking of cedar. Except for alder, cedar has the poorest yields, and stumpage prices are relatively low. Second-growth cedar is relatively defect-free and the species is immune to dwarf mistletoe. Western redcedar is difficult to establish on some sites. Cedar is highly susceptible to laminated root rot in northeast Washington and Idaho and should not be grown on infested sites in these areas.

Port-Orford-cedar (*Chamaecyparis lawsoniana*) is similar to western redcedar in degree of susceptibility to laminated root rot and may be substituted. The much higher stumpage price of Port-Orford-cedar would yield higher PNVs than western redcedar. Alaska yellow cedar (*C. nootkatensis*) and incense cedar *(Libocedrus decurrens*) are also similar to western redcedar in degree of susceptibility and could be substituted for western redcedar on appropriate sites.

Red alder (*Alnus rubra*). Alder is the poorest alternative species to substitute for Douglas-fir in root-diseased areas. This is mainly due to poor yields, in terms of board feet, and extremely low stumpage prices that result in poor financial returns at the end of the first rotation. Harvest income at the end of the first rotation constitutes the largest portion of the PNV after three rotations. The main benefit from alder is its fertilizing and sanitizing effect on the site. Besides fixing nitrogen, there is some evidence that the nitrates produced by alder roots promote certain soil microorganisms that are antagonistic to *Phellinus weirii*. After a rotation of alder, which is immune to *P. weirii*, the site can be planted to Douglas-fir and theoretically produce normal yields for all succeeding rotations.

Ponderosa pine (*Pinus ponderosa*). In East Side stands, ponderosa pine is the best species to substitute for white fir in laminated root rot areas. Ponderosa pine produces greater yields and has much higher stumpage prices than either larch or lodgepole pine. At high elevations, snowbreakage may limit ponderosa pine management; in which case noble fir, lodgepole pine, or white pine could be planted instead of ponderosa pine. Ponderosa pine is relatively defect-free. In many areas, dwarf mistletoe (*A. campylopodum*) or bark beetles (*Dendroctonus brevicomis* and *D. ponderosae*) are common, but losses should be insignificant where stocking level control is performed. Infested sites planted with ponderosa pine can be planted with white fir or Douglas-fir after one pine rotation with little chance of root disease carryover.

Lodgepole pine (*Pinus contorta*). Of all East Side species analyzed, lodgepole pine is the second best species to substitute for white fir in root-diseased areas. However, unless the stand has a 50 percent initial infection level, it is generally better to grow a short rotation of Douglas-fir or white fir than to plant lodgepole pine. When planting ponderosa pine or stump treatments is not an option, lodgepole should be planted after the first rotation stand of fir is merchantable. Lodgepole yields and stumpage prices are the lowest of East Side species, but high resistance to laminated root rot makes it a better species to plant than larch. Lodgepole is relatively free of defect. Dwarf mistletoe (*A. americanum*) and mountain pine beetle (*D. ponderosae*) can cause substantial losses, but stocking level control should greatly reduce damage. Infected areas planted with lodgepole should not be planted with white fir or Douglas-fir in future rotations because of possible root disease carryover from pine to fir.

Western larch (*Larix occidentalis*). Western larch is the poorest alternate species to substitute for white fir in laminated root rot sites because of low yields, poor stumpage prices, and some loss due to butt rot and mortality. As with lodgepole, it is better to grow a short rotation of fir then plant larch after the fir is merchantable. Dwarf mistletoe (*A. laricis*) causes more larch mortality than any other pest. However, prevention and suppression efforts should decrease losses due to dwarf mistletoe. Infected areas planted with larch should not be planted with white fir or Douglas-fir in future rotations because of root disease carryover.

Other species. Several other commercial tree species that were not analyzed in this report could be planted on root-diseased sites as a substitute for Douglas-fir or white fir. Sitka spruce (*Picea sitchensis*) and Engelmann spruce (*P. engelmannii*) are both intermediately susceptible to laminated root rot (Hadfield and Johnson 1977). Stumpage prices for Sitka spruce are higher than hemlock but yields are probably lower. Stumpage prices and probably yields for Englemann spruce are lower than larch, so PNV's of treatments with spruce may not exceed those of managing white fir on diseased sites. Other commercial hardwood species such as bigleaf maple (*Acer macrophyllum*), Oregon white oak (*Quercus garryana*), or black cottonwood (*Populus trichocorpa*) are immune to laminated root rot and could be planted instead of Douglas-fir. Black cottonwood has much higher stumpage rates than red alder and would yield a correspondingly higher PNV. Although hardwood yields and stumpage prices are relatively low, it is assumed that Douglas-fir can be replanted safely after one rotation with these species.

Value of Early Disease Detection.

In addition to the benefits of treatment, the economic data of this evaluation also show the value of early disease identification. After a harvest, the presence and problems associated with Phellinus weirii may take several years to become apparent. When the effects materialize and the problem is recognized, as indicated in this study, some level of treatment may be economically desirable. In the meantime, several years of production will have been lost.

If delay of an economically viable treatment results from not identifying the presence of the disease, an economic cost may result from having missed an investment opportunity. This opportunity cost for a particular treatment can be determined from Tables 1,3,5,7 as the difference in PNV gain resulting from delay in the application of a given control measure. For example, consider applying a hemlock treatment at the beginning and at precommercial thinning during the first rotation on a good West Side site with a 50% infection level. If the disease is not detected until precommercial thinning at age 15, there results a reduction in financial gain to treatment from $561 to $414, or $147 per acre.

Similar evaluations of the cost of treatment delay can be made between other points in time. This perspective on the economic benefit of early disease detection points out the need to make good disease assessments, particularly before regenerating a harvested site when the opportunity costs are highest.

CONCLUSIONS

A comparison of present net values (4 percent discount) of several control strategies on 18 hypothetical sites indicates that most treatments are superior to continuous rotations of Douglas-fir (West Side) or white fir (East Side) on sites affected by laminated root rot. Definite differences in PNV occur among treatments, and, with some exceptions, these differences do not vary among site classes or disease levels.

Ranking of PNV differences of stump treatment and species planted in infected sites shows a clear hierarchy that is greatly influenced by potential yield and stumpage prices of the species. Degree of disease resistance does not appear to be as strong a factor, especially in West Side stands. However, should actual yield loss caused by laminated root rot be much greater than assummed for the various species, degree of resistance may become a more important factor governing PNV.

This economic analysis of laminated root rot control strategies was performed on hypothetical sites using averages, generalizations, and some assumptions that have weak supporting data. Even with these limitations, we hope that this report will provide a method for forest land managers to economically analyze root disease control measures on a site-by-site basis. With more accurate local knowledge of yields, stumpage prices, and species susceptibility, land managers may better assess treatment efficiency by using the methods presented in this report.

The Bottom Line

1. Most treatments are better than continued growing of species highly susceptible to laminated root rot.

2. Treat infested sites at the beginning of the first rotation. Early disease detection and treatment, preferably before stand harvest, will increase financial gains. In most cases, if a site is already planted with susceptible species, treat only after the stand becomes merchantable.

3. Treat stands with the highest disease levels and site index first; disease level being the more critical.

4. Plant infested sites with species other than Douglas-fir or white fir to increase financial gain. Hemlock is best on the West Side and ponderosa pine is best on the East Side.

5. Consider stump treatment, either excavation or fumigation, as a method of reducing disease, especially where alternative species are neither practical nor desirable.

Literature Cited

Chambers, C. J.
1974. Empirical yield tables for predominantly alder stands in western Washington. DNR Report No. 31, Washington State Dept. of Natural Resources, Olympia, WA, 70 p.

Chambers, C. J.
1980. Empirical growth and yield tables for the Douglas-fir zone. DNR Report No. 41, Washington State Dept. of Natural Resources, Olympia, WA, 50 p.

Chambers, C. J. and F. M. Wilson.
1978. Empirical yield tables for the western hemlock zone. DNR Report No. 22R, Washington State Dept. of Natural Resources, Olympia, WA, 12 p.

Childs, T. W. and K. R. Shea.
1967. Annual losses from disease in Pacific Northwest Forests. USDA For. Serv. Res. Bull. PNW-20, Pacific Northwest Forest and Range Experiment Station, Portland, OR, 19 p.

Cochran, P. H.
1979. Gross yields for even-aged stands of Douglas-fir and white or grand fir east of the Cascades in Oregon and Washington. USDA For. Serv. Res. Pap. PNW-267, Pacific Northwest Forest and Range Experiment Station, Portland, OR, 17 p.

Dahms, W. G.
1964. Gross and net yield tables for lodgepole pine. USDA For. Serv. Res. Pap. PNW-8, Pacific Northwest Forest and Range Experiment Station, Portland, OR, 14 p.

Filip, G. M. and L. F. Roth
1977. Stump injections with soil fumigants to eradicate Armillariella mellea from young-growth ponderosa pine killed by root rot. Can. J. For. Res. 7:226-231.

Filip, G. M. and D. J. Goheen.
1982. Hazards of root disease in Pacific Northwest recreation sites. J. of For. 80(3):163-164.

Filip, G. M. and D. J. Goheen.
1984. Root diseases cause severe mortality in white and grand fir stands of the Pacific Northwest. For. Sci. 30:138-142.

Franklin, J. F.
1982. Ecology of noble fir, pp. 59-69. In "Proceedings of the Biology and Management of True Fir in the Pacific Northwest Symposium," edited by C. D. Oliver and R. M. Kenady, Univ. of Wash., Seattle, 344 p.

Goheen, D. J., S. J. Frankel, and E. Michaels
1984. Root disease survey of Douglas-fir plantations, Alsea Ranger District, Siuslaw National Forest. Forest Pest Management, Pacific Northwest Region, USDA For. Serv., Portland, OR, 12 p.

Hadfield, J. S. and D. W. Johnson.
1977. Laminated root rot: a guide for reducing and preventing losses in Oregon and Washington forests. Forest Pest Management, Pacific Northwest Region, USDA For. Serv., Portland, OR, 16 p.

Haig, I. T.
1932. Second-growth yield, stand, and volume tables for western white pine type, USDA For. Serv. Tech. Bull. No. 323, Washington, D.C., 67 p.

Hall, F. C.
1973. Plant communities of the Blue Mountains in eastern Oregon and southwestern Washington. R6 Area Guide 3-1, Pacific Northwest Region, USDA For. Serv., Portland, OR, 62 p.

Meyer, W. H.
1961. Yield of even-aged stands of ponderosa pine. USDA For. Serv. Tech. Bull. No. 630, Washington, D.C., 59 p.

Roth, L. F., C. G. Shaw III, and L. Rolph.
1977. Marking ponderosa pine to combine commercial thinning and control of Armillaria root rot. J. of For. 75(10):644-647.

Ruderman, F. K.
1982. Production, prices, employment, and trade in Northwest forest industries, second quarter 1982. Pacific Northwest Forest and Range Experiment Station, USDA For. Serv., Portland, OR, 64 p.

Schmidt, W. C., R. C. Shearer, and A. L. Roe.
1976. Ecology and silviculture of western larch forests. Tech. Bull. No. 1520. USDA Forest Service. 97 p.

Smith, H. G., J. Walters, and J. Wiker.
1961. Preliminary estimates of growh and yield of western redcedar. Faculty of Forestry Research Paper 42. Vancouver, British Columbia, 8 p.

Steinbrenner, E. C.
1976. Soil-site relationships and comparative yields of western hemlock and Douglas-fir, pp. 236-238. In "Proceedings-Western Hemlock Management Conference," edited by W. A. Atkinson and R. J. Zasoski, Univ. of Wash., Seattle, 317 p.

Thies, W. G. 1984. Laminated root rot: the quest for control. J. of For. 82:345-356.

Thies, W. G. and E. E. Nelson.
1982. Control of Phellinus weirii in Douglas-fir stumps by the fumigants chloropicrin, allyl alcohol, Vapam, or Vorlex. Can. J. For. Res. 12:528-532.

Tkacz, B. M. and E. M. Hansen.
1982. Damage by laminated root rot in two succeeding stands of Douglas-fir. J. of For. 80:788-791.

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Table 1--Financial gain (difference in PNV) after three rotations of treating stands affected by laminated root rot, West Side, 4% discount rate. A negative number indicates a loss.

TREATMENT	Good Site (DF_{50} = 120) DISEASE LEVEL 10%	35%	50%	Ave. Site (DF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Poor Site (DF_{50} = 80) DISEASE LEVEL 10%	35%	50%
	DOLLARS PER ACRE								
Untreated Douglas-fir	0	0	0	0	0	0	0	0	0
AGE 1									
Stump*	118	411	544	56	197	265	17	59	79
Hemlock	120	414	561	84	295	406	52	179	251
Cedar	21	72	69	13	46	50	9	31	40
Pine	26	89	94	22	73	88	16	55	73
Alder	5	15	-12	-6	-20	-45	-7	-24	-39
Noble fir	90	309	413	55	188	256	29	57	137
AGE 15									
Stump	53	185	230	24	83	102	0	-1	-7
Hemlock	90	309	414	39	133	179	23	77	108
Cedar	-26	-96	-169	-25	-86	-139	-19	-67	-100
Pine	-15	-52	-108	-17	-61	-102	-15	-54	-82
Alder	-5	-21	-62	-14	-51	-88	-15	-53	-81
Noble fir	-27	-42	-81	-35	-88	-133	-26	-171	-103
AGE 45, 55 or 65**									
Stump	49	179	226	29	110	140	15	56	74
Hemlock	50	177	223	33	123	159	22	80	109
Cedar	15	69	64	16	66	77	12	45	59
Pine	22	90	94	20	79	96	14	52	69
Alder	9	46	31	12	51	56	9	37	47
Noble fir	40	152	183	27	102	128	15	57	76
AGE 60, 70 or 80									
Stump	33	110	129	15	46	54	5	15	22
Hemlock	29	103	107	16	54	65	7	24	31
Cedar	5	10	-11	3	6	-3	1	2	1
Pine	6	14	-5	4	11	4	2	6	6
Alder	0	-9	-37	-1	-8	-22	-1	-6	-11
Noble fir	22	72	75	10	34	36	4	6	15

*Stump removal or fumigation

**Ages correspond to good, average, and poor sites

Table 2--Numerical ranking of differences in PNV after three rotations of treating stands affected by laminated root rot, West Side, 4% discount rate.

TREATMENT	Good Site (DF_{50} = 120) DISEASE LEVEL 10%	35%	50%	Ave. Site (DF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Poor Site (DF_{50} = 80) DISEASE LEVEL 10%	35%	50%
Untreated Douglas-fir	20	20	17	19	19	18	18	18	18
AGE 1									
Stump	2	2	2	2	2	2	5	4	5
Hemlock	1	1	1	1	1	1	1	1	1
Cedar	14	13	14	14	14	15	12	12	12
Pine	11	12	12	9	10	10	6	8	8
Alder	19	17	20	21	21	21	21	21	21
Noble fir	3	4	4	3	3	3	2	5	2
AGE 15									
Stump	5	5	5	8	8	8	19	19	19
Hemlock	4	3	3	4	4	4	3	3	4
Cedar	24	25	25	24	24	25	24	24	24
Pine	23	24	24	23	23	23	23	23	23
Alder	22	22	22	22	22	22	22	22	22
Noble fir	25	23	23	25	25	24	25	25	25
AGE 45, 55 or 65									
Stump	7	6	6	6	6	6	8	7	7
Hemlock	6	7	7	5	5	5	4	2	3
Cedar	15	15	15	12	11	11	10	10	10
Pine	13	11	11	10	9	9	9	9	9
Alder	16	16	16	15	13	13	11	11	11
Noble fir	8	8	8	7	7	7	7	6	6
AGE 60, 70 or 80									
Stump	9	9	9	13	15	14	14	14	14
Hemlock	10	10	10	11	12	12	13	13	13
Cedar	18	19	19	18	18	19	17	17	17
Pine	17	18	18	17	17	17	16	16	16
Alder	21	21	21	20	20	20	20	20	20
Noble fir	12	14	13	16	16	16	15	15	15

Table 3--Financial gain (differences in PNV) after three rotations of treating stands affected by laminated root rot, East Side, 4% discount rate. A negative number indicates a loss.

TREATMENT	Good Site (WF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Ave. Site (WF_{50} = 75) DISEASE LEVEL 10%	35%	50%	Poor Site (WF_{50} = 57) DISEASE LEVEL 10%	35%	50%
	DOLLARS PER ACRE								
Untreated White fir	0	0	0	0	0	0	0	0	0
AGE 1									
Stump	28	85	47	5	21	25	-13	-44	-65
Ponderosa	50	164	159	22	76	105	11	37	52
Lodgepole	-6	-34	-123	-5	-16	-26	-2	-5	-9
Larch	-9	-47	-137	-7	-25	-37	-2	-8	-12
AGE 20									
Stump	0	-12	-91	-9	-32	-49	-11	-40	-58
Ponderosa	-9	-47	-156	-12	-41	-81	-9	-32	-67
Lodgepole	-16	-69	-193	-14	-48	-92	-10	-34	-69
Larch	-23	-98	-230	-18	-64	-113	-12	-41	-79
AGE 60, 70 or 80									
Stump	8	21	-62	4	18	22	6	23	32
Ponderosa	10	29	-52	5	21	26	7	26	35
Lodgepole	2	2	-90	2	12	13	6	23	31
Larch	2	2	-91	2	11	12	6	23	31
AGE 80, 90 or 100									
Stump	6	20	24	2	8	9	0	1	1
Ponderosa	7	25	31	2	8	9	1	3	3
Lodgepole	-1	-4	-10	0	-2	-5	0	-1	-1
Larch	-1	-5	-12	-1	-3	-6	0	-1	-2

Table 4--Numerical ranking of differences in PNV after three rotations of treating stands affected by laminated root rot, East Side, 4% discount rate.

TREATMENT	Good Site (WF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Ave. Site (WF_{50} = 75) DISEASE LEVEL 10%	35%	50%	Poor Site (WF_{50} = 57) DISEASE LEVEL 10%	35%	50%
Untreated									
White fir	10	9	5	9	9	9	8	8	8
AGE 1									
Stump	2	2	2	2	2	2	17	17	14
Ponderosa	1	1	1	1	1	1	1	1	1
Lodgepole	13	13	13	12	12	12	11	10	11
Larch	15	14	14	13	13	13	12	12	12
AGE 20									
Stump	9	12	11	14	14	14	15	15	13
Ponderosa	14	15	15	15	15	15	13	13	15
Lodgepole	16	16	16	16	16	16	14	14	16
Larch	17	17	17	17	17	17	16	16	17
AGE 60, 70 or 80									
Stump	4	5	9	4	4	4	3	3	3
Ponderosa	3	3	8	3	3	3	2	2	2
Lodgepole	7	7	10	7	5	5	4	4	4
Larch	8	8	12	8	6	6	5	5	5
AGE 80, 90 or 100									
Stump	6	6	4	6	8	8	6	7	7
Ponderosa	5	4	3	5	7	7	7	6	6
Lodgepole	11	10	6	10	10	10	9	9	9
Larch	12	11	7	11	11	11	10	10	10

Table 5--Financial gain (difference in PNV) after three rotations of treating stands affected by laminated root rot, West Side, 7% discount rate. A negative number indicates a loss.

TREATMENT	Good Site (DF_{50} = 120) DISEASE LEVEL 10%	35%	50%	Ave. Site (DF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Poor Site (DF_{50} = 80) DISEASE LEVEL 10%	35%	50%
	DOLLARS PER ACRE								
Untreated Douglas-fir	0	0	0	0	0	0	0	0	0
AGE 1									
Stump	-15	-49	-72	-25	-84	-121	-29	-101	-145
Hemlock	14	50	71	8	28	40	4	13	19
Cedar	1	4	4	1	3	3	1	2	2
Pine	2	6	7	1	5	7	1	4	5
Alder	-5	-17	-26	-3	-9	-14	-1	-4	-6
Noble fir	10	36	51	5	17	25	2	4	10
AGE 15									
Stump	-12	-42	-62	-16	-55	-79	-18	-63	-91
Hemlock	5	18	26	-2	-7	-10	-4	-13	-18
Cedar	-11	-39	-57	-8	-29	-41	-7	-23	-33
Pine	-11	-38	-55	-8	-28	-41	-6	-23	-32
Alder	-11	-37	-54	-8	-28	-41	-6	-23	-32
Noble fir	-16	-48	-68	-11	-35	-50	-8	-36	-38
AGE 45, 55 or 65									
Stump	9	32	44	5	20	27	3	9	13
Hemlock	10	37	52	6	23	32	3	11	15
Cedar	9	35	48	6	22	30	3	11	15
Pine	10	35	49	6	22	31	3	11	15
Alder	9	34	47	6	22	30	3	10	15
Noble fir	10	37	51	6	22	31	3	11	15
AGE 60, 70 or 80									
Stump	0	0	1	0	-1	-1	0	0	0
Hemlock	1	2	2	0	1	1	0	0	0
Cedar	0	0	0	0	0	0	0	0	0
Pine	0	0	0	0	0	0	0	0	0
Alder	0	-1	-2	0	0	0	0	0	0
Noble fir	0	2	2	0	0	0	0	0	0

Table 6--Numerical ranking of differences in PNV after three rotations of treating stands affected by laminated root rot, West Side, 7% discount rate.

TREATMENT	Good Site (DF_{50} = 120) DISEASE LEVEL 10%	35%	50%	Ave. Site (DF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Poor Site (DF_{50} = 80) DISEASE LEVEL 10%	35%	50%
Untreated Douglas-fir	17	17	15	15	15	14	15	15	14
AGE 1									
Stump	24	25	25	25	25	25	25	25	25
Hemlock	1	1	1	1	1	1	1	1	1
Cedar	11	11	11	10	10	10	10	10	10
Pine	10	10	10	9	9	9	9	9	9
Alder	19	19	19	18	19	19	18	18	18
Noble fir	2	4	3	8	8	8	8	8	8
AGE 15									
Stump	23	23	23	24	24	24	24	24	24
Hemlock	9	9	9	19	18	18	19	19	19
Cedar	22	22	22	22	22	22	22	22	22
Pine	21	21	21	21	21	21	21	21	21
Alder	20	20	20	20	20	20	20	20	20
Noble fir	25	24	24	23	23	23	23	23	23
AGE 45, 55 or 65									
Stump	8	8	8	7	7	7	7	7	7
Hemlock	3	2	2	2	2	2	2	2	2
Cedar	6	6	6	5	5	5	5	5	5
Pine	5	5	5	4	6	4	4	4	4
Alder	7	7	7	6	4	6	6	6	6
Noble fir	4	3	4	3	3	3	3	3	3
AGE 60, 70 or 80									
Stump	16	16	14	17	17	17	17	17	17
Hemlock	12	12	12	11	11	11	11	11	11
Cedar	15	15	17	14	14	15	13	13	14
Pine	14	14	16	13	13	13	13	14	13
Alder	18	18	18	16	16	16	16	16	16
Noble fir	13	13	13	12	12	12	12	12	12

Table 7--Financial gain (difference in PNV) after three rotations of treating stands affected by laminated root rot, East Side, 7% discount rate. A negative number indicates a loss.

TREATMENT	Good Site (WF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Ave. Site (WF_{50} = 75) DISEASE LEVEL 10%	35%	50%	Poor Site (WF_{50} = 57) DISEASE LEVEL 10%	35%	50%
	DOLLARS PER ACRE								
Untreated White fir	0	0	0	0	0	0	0	0	0
AGE 1									
Stump	-22	-76	-116	-24	-83	-119	-25	-87	-125
Ponderosa	4	12	11	1	4	6	0	2	2
Lodgepole	-1	-3	-11	0	-1	-2	0	0	0
Larch	-1	-4	-12	0	-2	-2	0	0	-1
AGE 20									
Stump	-11	-39	-61	-11	-40	-57	-12	-41	-58
Ponderosa	-5	-19	-43	-4	-15	-32	-4	-14	-30
Lodgepole	-5	-18	-41	-4	-15	-32	-4	-14	-30
Larch	-6	-21	-47	-5	-17	-35	-4	-15	-33
AGE 60, 70 or 80									
Stump	2	8	2	1	4	6	1	3	4
Ponderosa	3	10	5	1	5	7	1	3	4
Lodgepole	3	9	5	1	5	7	1	3	4
Larch	3	9	5	1	5	7	1	3	4
AGE 80, 90 or 100									
Stump	0	0	-1	0	0	0	0	0	0
Ponderosa	0	0	0	0	0	0	0	0	0
Lodgepole	0	0	0	0	0	0	0	0	0
Larch	0	0	0	0	0	0	0	0	0

Table 8--Numerical ranking of differences in PNV after three rotations of treating stands affected by laminated root rot, East Side, 7% discount rate.

TREATMENT	Good Site (WF_{50} = 100) DISEASE LEVEL 10%	35%	50%	Ave. Site (WF_{50} = 75) DISEASE LEVEL 10%	35%	50%	Poor Site (WF_{50} = 57) DISEASE LEVEL 10%	35%	50%
Untreated White fir	7	7	7	7	7	7	6	7	7
AGE 1									
Stump	17	17	17	17	17	17	17	17	17
Ponderosa	1	1	1	4	5	5	5	5	5
Lodgepole	11	11	11	11	11	11	11	11	11
Larch	12	12	12	12	12	12	12	12	12
AGE 20									
Stump	16	16	16	16	16	16	16	16	16
Ponderosa	14	14	14	14	14	14	14	14	14
Lodgepole	13	13	13	13	13	13	13	13	13
Larch	15	15	15	15	15	15	15	15	15
AGE 60, 70 or 80									
Stump	5	5	5	4	4	4	4	4	4
Ponderosa	2	2	2	1	1	1	1	1	1
Lodgepole	3	3	3	2	2	2	1	2	2
Larch	3	3	4	2	3	2	1	2	2
AGE 80, 90 or 100									
Stump	10	10	10	10	10	10	10	10	10
Ponderosa	6	6	6	6	6	6	6	6	6
Lodgepole	8	8	8	7	8	8	6	8	8
Larch	8	9	9	7	8	8	6	8	8

Table 9--Gross board foot yields used for economically analyzing West Side species

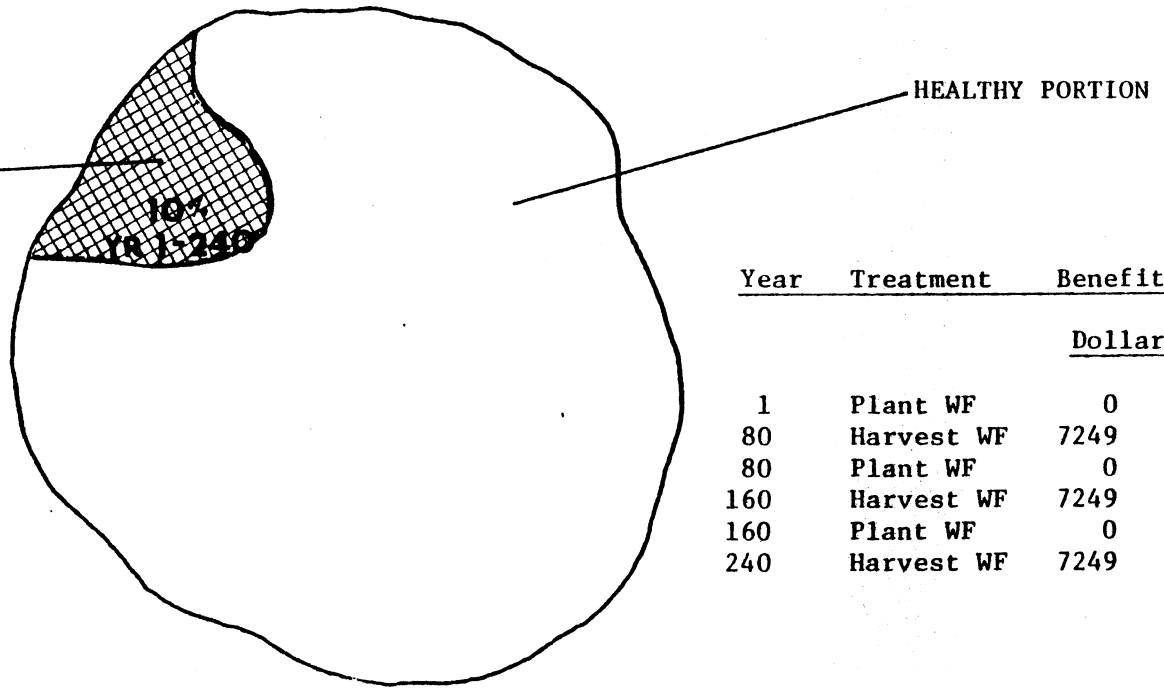
Species	SI_{50}	Comm. Thin Age	Comm. Thin BF/AC	Normal Harvest Age	Normal Harvest BF/AC	Harvest Age	Harvest BF/AC	Harvest Age	Harvest BF/AC
					GOOD SITE				
D. Fir	120	45	28179	60	48836	75	69456	110	112000
W. Hemlock	105	45	48436	60	56211	75	79533	---	-------
Red Alder	96	45	17282	60	27396	75	27396	---	-------
W. Redcedar	96	--	-----	60	26550	75	32180	105	41400
White Pine	70	--	-----	60	33800	75	56150	105	95700
Noble Fir	115	--	-----	60	64258	75	91389	105	145000
					AVERAGE SITE				
D. Fir	100	55	28116	70	43590	85	58468	110	81000
W. Hemlock	90	55	36523	70	55215	85	73908	---	-------
Red Alder	80	55	16525	70	18969	85	18969	---	-------
W. Redcedar	84	--	-----	70	25430	85	29810	125	37350
White Pine	60	--	-----	70	35650	85	55100	125	94350
Noble Fir	105	--	-----	70	57355	85	76932	125	110000
					POOR SITE				
D. Fir	80	65	23117	80	33008	95	41833	110	48000
W. Hemlock	73	65	32390	80	45834	95	75930	---	-------
Red Alder	60	65	14051	80	14051	95	14051	---	-------
W. Redcedar	71	--	-----	80	22280	95	26100	145	31050
White Pine	50	--	-----	80	33300	95	49200	145	82000
Noble Fir	85	--	-----	80	43432	95	55043	145	95000

Table 10--Gross board foot yields used for economically analyzing East Side species

Species	SI_{50}	Com. Thin Age	BF/Ac.	Normal Harvest Age	BF/Ac.	Harvest Age	BF/Ac.	Harvest Age	BF/Ac.
				GOOD SITE					
White fir	100	60	45142	80	88407	100	108918	---	---
West. larch	75	60	20353	80	39904	100	47790	---	---
Lodgepole pine	65	60	16924	80	33854	100	42210	---	---
Ponderosa pine	80	60	29450	80	52425	100	60075	140	113800
				AVERAGE SITE					
White fir	75	70	38322	90	72371	110	87750	---	---
West. larch	55	70	15686	90	28625	110	33118	---	---
Lodgepole pine	45	70	13160	90	25047	110	30359	---	---
Ponderosa pine	65	70	20150	90	34425	110	38250	160	70600
				POOR SITE					
White fir	57	80	32541	100	41230	120	65250	---	---
West. larch	40	80	11408	100	19832	120	22365	---	---
Lodgepole pine	31	80	9619	100	17678	120	20967	---	---
Ponderosa pine	46	80	13206	100	22185	120	24480	180	42420

Figure 1--Start of the First Rotation Treatment with Ponderosa Pine

-Good Site- 10% Disease Level



Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant PP	0	235
80	Harvest PP	6239	0
80	Plant PP	0	235
160	Harvest PP	6239	0
160	Plant PP	0	235
240	Harvest PP	6239	0

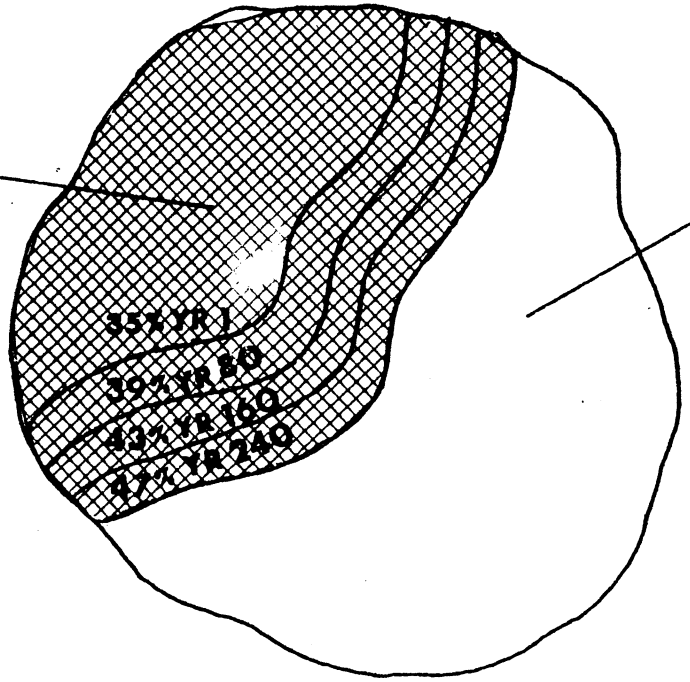
Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant WF	0	235
80	Harvest WF	7249	0
80	Plant WF	0	235
160	Harvest WF	7249	0
160	Plant WF	0	235
240	Harvest WF	7249	0

ENTIRE STAND

Year	Treatment	Benefit	Cost
		Dollars per Acre	
1	Plant PP&WF	0	235
80	Harvest PP&WF	7148 = (6239 x .10) + (7249 x .90)	0
80	Plant PP&WF	0	235
160	Harvest PP&WF	7148	0
160	Plant PP&WF	0	235
240	Harvest PP&WF	7148	0

Figure 2--Precommercial Treatment with Hemlock

-Poor Site- 35% Disease Level



Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant DF	0	255
15	Destroy DF Plant WH	0	150
80	Harvest WH	4431	0
80	Plant WH	0	255
160	Harvest WH	6270	0
160	Plant WH	0	255
240	Harvest WH	6270	0

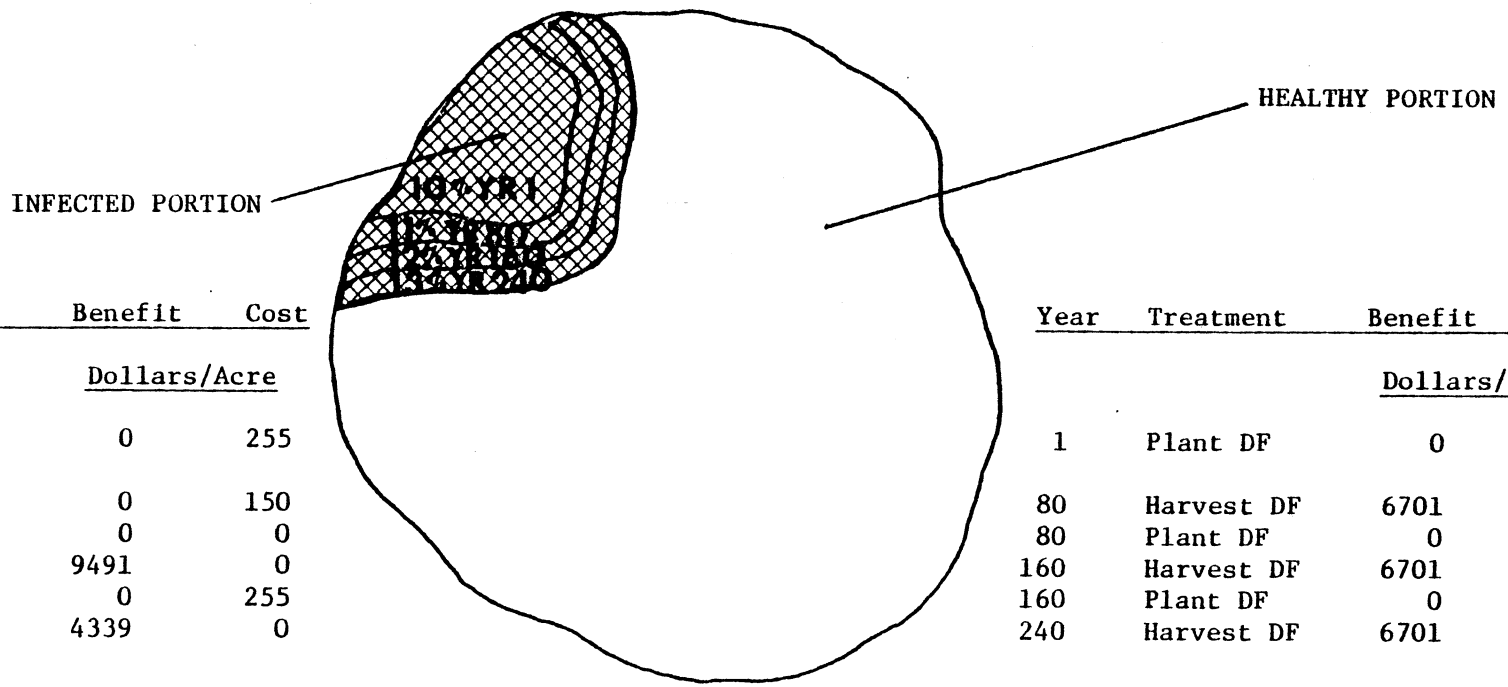
Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant DF	0	255
15	None	0	0
80	Harvest DF	6701	0
80	Plant DF	0	255
160	Harvest DF	6701	0
160	Plant DF	0	255
240	Harvest DF	6701	0

ENTIRE STAND

Year	Treatment	Benefit	Cost
		Dollars per Acre	
1	Plant DF	0	255
15	Destroy DF-Plant WH	0	53 = (150 x .35)
80	Harvest WH&DF	5816 = (4431 x .39) + (6701 x .61)	0
80	Plant WH&DF	0	255
160	Harvest WH&DF	6516 = (6270 x .43) + (6701 x .57)	0
160	Plant WH&DF	0	255
240	Harvest WH&DF	6498 = (6270 x .47) + (6701 x .53)	0

Figure 3--Precommercial Treatment with Noble Fir

-Poor Site- 10% Disease Level



Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant DF	0	255
15	Destroy DF		
	Plant NF	0	150
80	None	0	0
160	Harvest NF	9491	0
160	Plant NF	0	255
240	Harvest NF	4339	0

Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant DF	0	255
80	Harvest DF	6701	0
80	Plant DF	0	255
160	Harvest DF	6701	0
160	Plant DF	0	255
240	Harvest DF	6701	0

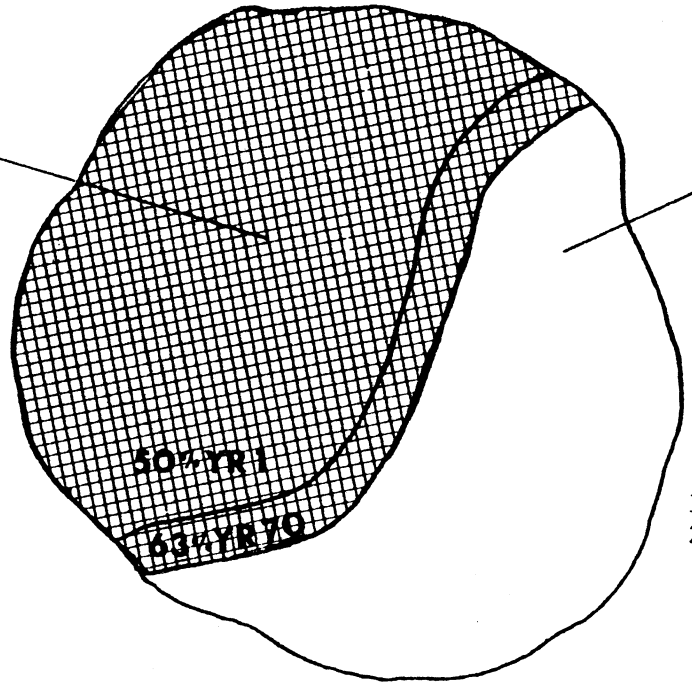
Year	Treatment	Benefit	Cost
		Dollars per Acre	
1	Plant DF	0	255
15	Destroy DF		
	Plant NF	0	15 = (150 x .10)
80	Harvest DF	5963 = (6701 x .89)	0
80	Plant DF	0	244 = (150 x .88)
160	Harvest DF&NF	7036 = (9491 x .12) + (6701 x .88)	0
160	Plant DF&NF	0	255
240	Harvest DF&NF	6394 = (4339 x .13) + (6701 x .87)	0

Figure 4--Commercial Thinning Treatment with Lodgepole Pine

-Ave. Site- 50% Disease Level

INFECTED PORTION

Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant WF	0	235
70	Harvest WF	786	0
70	Plant LP	0	235
90	None	0	0
180	Harvest LP	836	0
180	Plant LP	0	235
270	Harvest LP	690	0



HEALTHY PORTION

Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant WF	0	235
70	None	0	0
90	Harvest WF	5934	0
90	Plant WF	0	235
180	Harvest WF	5934	0
180	Plant WF	0	235
270	Harvest WF	5934	0

ENTIRE STAND

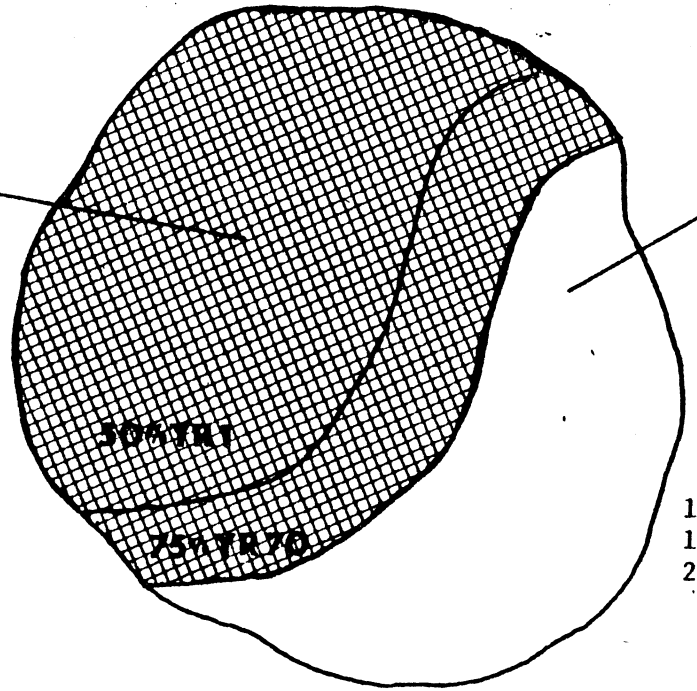
Year	Treatment	Benefit	Cost
		----------Dollars per Acre----------	
1	Plant WF	0	235
70	Harvest WF	495 = (786 x .63)	0
70	Plant LP	0	148 = (235 x .63)
90	Harvest WF	2196 = (5934 x .37)	0
90	Plant WF	0	87 = (235 x .37)
180	Harvest WF&LP	2722 = (836 x .63) + (5934 x .37)	0
180	Plant WF&LP	0	235
270	Harvest WF&LP	2630 = (690 x .63) + (5934 x .37)	0

Figure 5--Start of Second Rotation Treatment with Stump Removal

-Ave. Site- 50% Disease Level

INFECTED PORTION

Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant DF	0	255
70	Harvest DF	2212	0
70	Stump & Plant DF	0	580
140	Harvest DF	7694	0
140	Plant DF	0	255
210	Harvest DF	7694	0



HEALTHY PORTION

Year	Treatment	Benefit	Cost
		Dollars/Acre	
1	Plant DF	0	255
70	Harvest DF	8849	0
70	Plant DF	0	255
140	Harvest DF	8849	0
140	Plant DF	0	255
210	Harvest DF	8849	0

ENTIRE STAND

Year	Treatment	Benefit	Cost
		----------Dollars per Acre----------	
1	Plant DF	0	255
70	Harvest DF	3871 = (2212 x .75) + (8849 x .25)	0
70	Stump & Plant DF	0	499 = (580 x .75) + (255 x 25
140	Harvest DF	7983 = (7694 x .75) + (8849 x .25)	0
140	Plant DF	0	255
210	Harvest DF	7983	0